Athos I Oil Spill
Restoration Scaling Paper for Injuries to Birds:
Habitat Enhancement at Mad Horse Creek and Blackbird Reserve; Oyster Reef Enhancement in the Delaware River

August 22, 2008

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Introduction

Trustee estimates of bird injuries attributable to the Athos oil spill are summarized in Table 1. Direct injuries totaled 3,308 adult birds, the majority (75 percent) of which were gulls and geese. Additional estimated lost production from mortality and reproductive failure (indirect injury) was 8,561 fledged young.

Table 1. Total (direct and indirect) estimated bird injury from the *Athos* oil spill by guild**.**

Guild	**Direct Injury (Adults)**	**Discounted Indirect Injury (Fledged Young)**		**Total (Adults and Fledged Young)**
	Died	**Lost Prod. (Mortality)**	**Lost Prod. (Reproductive Failure)**	
Dabbling ducks	605	1,187	577	2,369
Diving ducks	82	163	24	269
Diving birds	64	92	2	158
Gulls	1,072	1,543	331	2,946
Shorebirds	55	79	0	134
Wading birds	10	14	3	27
Swans/geese	1,416	3,369	1,171	5,956
Kingfishers	4	6	0	10
Total	**3,308**	**6,453**	**2,108**	**11,869**

For restoration scaling, guilds are grouped by primary diet (invertebrates, fish/omnivorous, and plants). Invertebrate-consuming guilds include dabbling ducks and shorebirds. Piscivorous or omnivorous consumers include diving ducks and birds, gulls, wading birds, and kingfishers. Primarily herbivorous birds include the swans and geese guild. To compensate for losses to species consuming primarily invertebrates, the Trustees propose to restore 25.4 acres of wetland habitat in Mad Horse Creek (Figure 11), located in Lower Alloway Creek Township, Salem County, NJ. To compensate for losses to piscivorous or omnivorous birds, the Trustees propose to create 72 acres of oyster reef in the Delaware River. To compensate for losses to primarily herbivorous birds, the Trustees propose to create 30 acres of wet meadow habitat and 100 acres of grassland habitat at Mad Horse Creek and to create 22.9 acres of goose habitat in the Blackbird Reserve Wildlife Area in New Castle County.

This restoration approach will benefit coastal bird communities in areas affected by the spill; is consistent with existing federal, state, and local restoration goals for the Delaware River and Bay; and is appropriate in light of the substantial spill-related injuries to birds. This combination of projects is also cost-effective. At Mad Horse Creek and Blackbird Reserve, the land is already government-owned, therefore eliminating the need for easement payments or land purchase. Available information indicates that sediment to be excavated in the marsh habitat targeted for restoration at Mad Horse Creek has low contaminant levels, eliminating the need for expensive treatment and/or off-site disposal. Grassland restoration will take place at Mad Horse Creek, and make use of sediments excavated as part of wetland and wet meadow restoration activities. The oyster reef project takes advantage of a program and resources already in place for on-going oyster restoration efforts throughout the Delaware River.

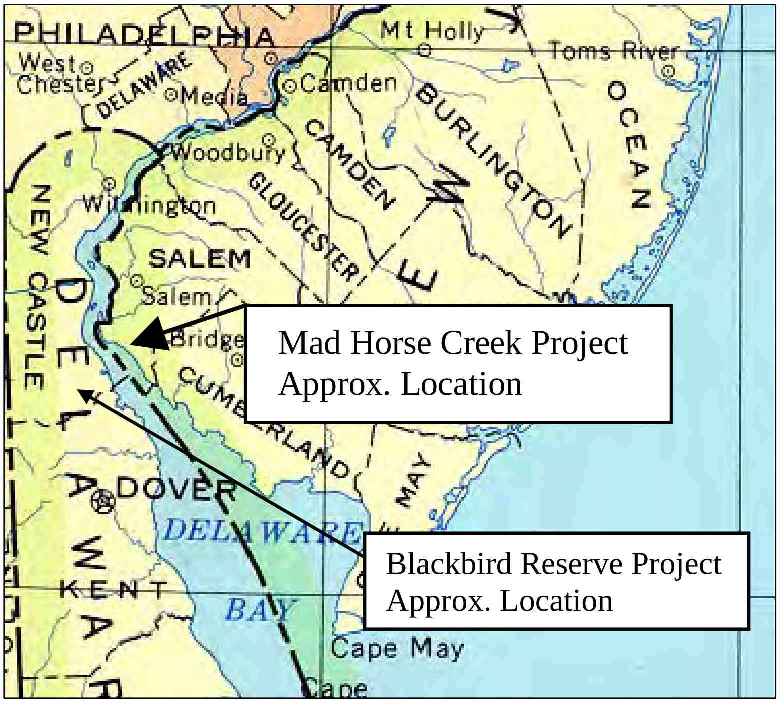

Figure 1. Approximate location of Mad Horse Creek restoration project.

Project Description - Mad Horse Creek

The proposed restoration site is on the former Quashne property, located in Lower Alloway Creek Township in Salem County New Jersey, and was acquired by the New Jersey Department of Environmental Protection (NJDEP) in 1997. The 260-acre property contains salt marshes, transitional wetlands (*Phragmites* dominant), agricultural lands and associated buildings, and is now part of the Mad Horse Creek Wildlife Management Area. Past agricultural practices on this property included altering and filling the brackish marsh fringe. These alterations have resulted in a *Phragmites* invasion of the wetland.

The NJDEP's Office of Natural Resource Restoration (ONRR) and the NOAA Restoration Center are now in the design phase of a tidal and freshwater wetland restoration project (Figure 12). The site location near the Delaware Bay, within tidal waters, will allow for the construction of *Spartina alterniflora* habitat at the appropriate elevations. Restoration will be accomplished through the removal of fill material and lowering the marsh elevation so that tidal inundation can occur. Wet meadow habitat also will be created through excavation at selected upland locations on-site. Options for disposal of the excavated sediment from restored marsh and wet meadow areas include on-site and off-site placement, with on-site being the most cost effective. On-site disposal also creates grassland habitat that will help compensate for *Athos* bird injuries[1].

The State of New Jersey will serve as the LIT for this project, with Trustee Council oversight.

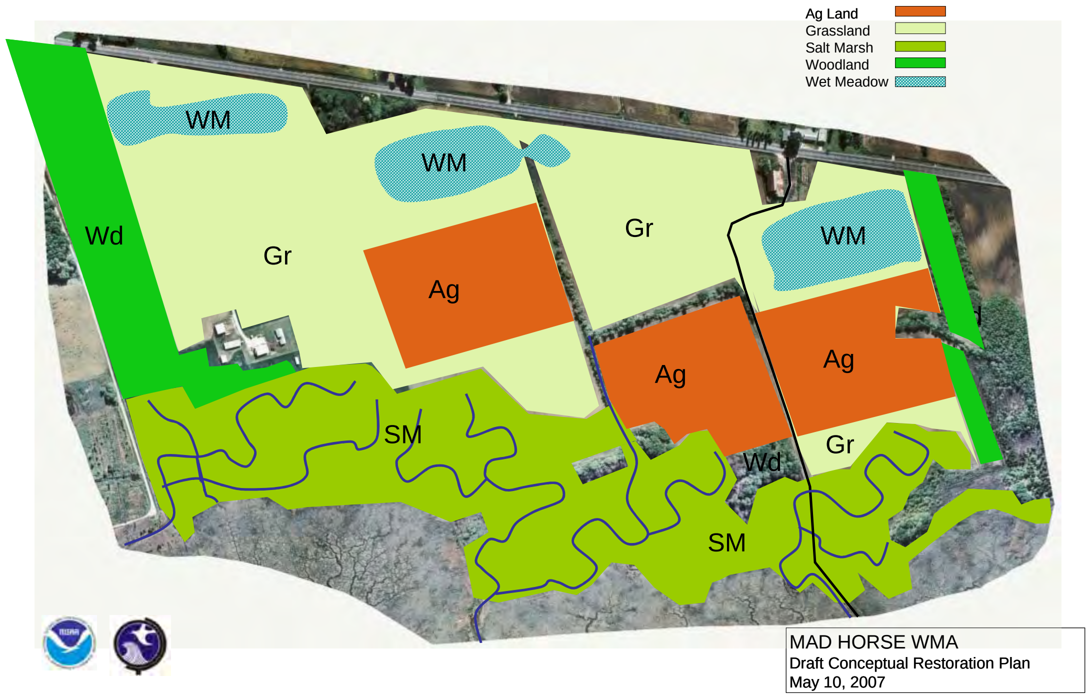

Figure 2. Mad Horse Creek conceptual restoration plan.

Project Description – Blackbird Reserve

The proposed site of this pond, pasture and agricultural food plot project is within the state-owned Blackbird Reserve Wildlife Area in southern New Castle County, Delaware. The 535-acre site is predominantly forested (71.4%), with 152.9 acres (28.6%) in open agricultural lands. In an effort to maintain habitat heterogeneity and provide wildlife habitat value, the DFW proposes restoration of these agricultural lands into a combination of forested areas, shallow wetland ponds, wildlife pastures and agricultural food plots. The latter three habitat types (shallow wetland ponds, pastures and agricultural food plots) will be restored to provide suitable migratory goose habitat as part of Athos restoration efforts (Figure 3). Existing lowland areas will be excavated to create two permanent shallow ponds surrounded by managed pastures designed to attract migratory geese. In addition, areas adjacent to the pastures will use agricultural practices to create wildlife food plots also designed to attract migrating geese. In

[1] While the Mad Horse Project also will involve the creation of woodland habitat, this project component will not generate benefits that compensate for *Athos*-related injuries. Costs for woodland habitat creation therefore are excluded from cost estimates developed for *Athos*-related restoration at Mad Horse Creek.

total, approximately 2.2 acres of ponds, 16 acres of pasture and 23.6 acres of food plots will be established.[2]

The slopes of the shallow wetland ponds will be planted in beneficial wetland plants and the pastures will be planted with cool season grasses, including white clover and a fescue mix (creeping red and chewing). The wildlife food plots will be established using agricultural practices and will be planted in corn, soybean or winter wheat; however, no more than 80% of the crop will be removed, providing both food and feeding habitat for migrating geese. The remaining 20% of crop left standing (4.7 acres) will be distributed along the perimeter of the fields to improve vegetative erosion control, as well as in thin strips or small blocks within the fields providing ideal winter feeding habitat for migrating geese.

The State of Delaware will serve as LIT for this project, with Trustee Council oversight.

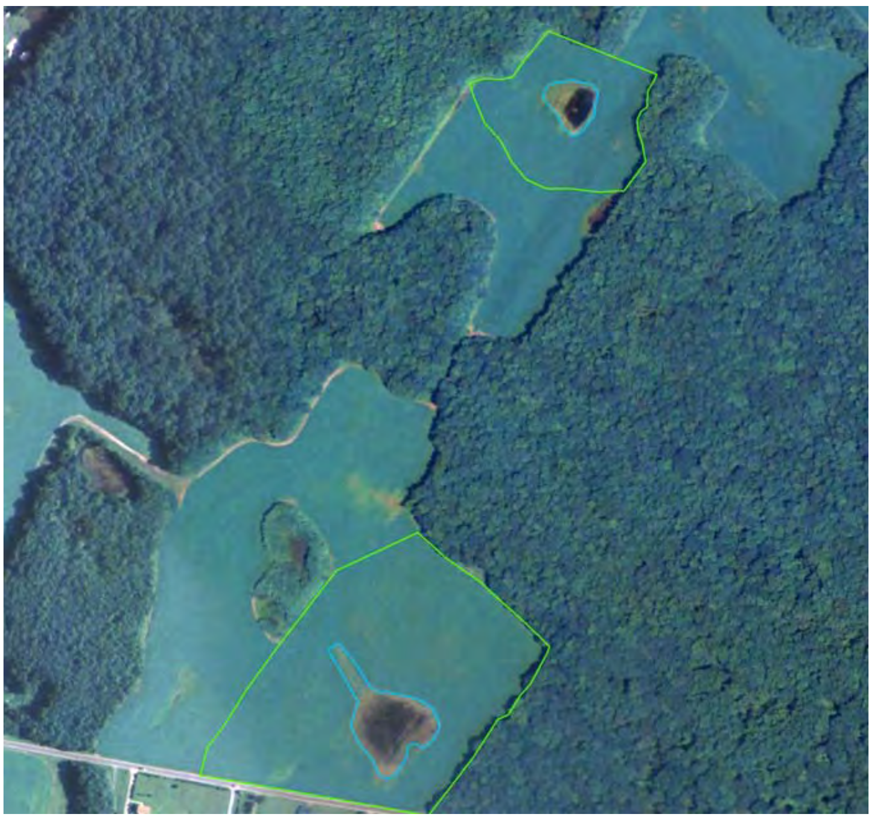

Figure 3. Proposed restoration projects at Blackbird Reserve. The targeted ponds are outlined in blue while the pasture areas are in neon green.

[2] The active agriculture component is 23.6 acres; 20 percent, or 4.7 acres, will be left unharvested as standing crop for geese.

Project Description - Oyster Reef Sanctuary

The Trustees propose to perform a direct placement project at a rate of roughly 2,000 bushels/acre in the Over the Bar beds on the DE side of the river. The Trustees propose to perform a recruitment/placement project in NJ waters on the Delaware River, due to state access to a high recruitment zone in the Cape Shore, NJ region of Delaware Bay. For the two-step process, clean shell (generally clam) is placed in an area with high recruitment of oyster spat, and then transferred to a lower salinity/lower mortality area for long-term survival. Consistent with standard practice in Delaware Bay, oyster reef will be created through placement of approximately 1,500 bushels of shell per acre in historic oyster bed areas with high spat settlement rates. The project will be implemented in the summer of 2009.

Between three to six months following initial shell placement, spatted cultch will be harvested and transported upstream into the Delaware River to areas with lower natural mortality rates (a lower salinity area with less disease and predation). The exact location of the transplanted spatted cultch will be as close to the spill site as is deemed appropriate for retaining suitable growth. The most likely location, due to available acreage and low disease rates, is the Middle Seed bed. Shell density for replanting in the nursery area is expected to be approximately 1,000 bushels/acre.

Scaling calculations for both project types assume that oyster survival on the transplanted reef will be approximately five years and that there will be no harvesting of the oysters during the initial 5-year period. No additional spatted cultch transplant events or other settlement augmentation efforts are proposed after the initial placement and/or transplant efforts. The Trustees recommend splitting the effort between a natural recruitment project and a two-step recruitment/transplant project to minimize risks of project failure. Due to productivity differences (and therefore cost per biomass differences) in the two projects, the project areas will be split in a 2:1 ratio of recruitment/transplant to natural recruitment, in order to provide the benefits of minimized risk at a reasonable cost.

Creating and enhancing oyster reefs will directly enhance benthic habitat, with increased biomass generated by the seeded oysters and biota associated with the reef. The invertebrate biomass in turn increases the fish biomass available to the ecosystem. Further description of the oyster reef sanctuary project is provided in the scaling paper for subtidal injuries.

The States of Delaware and New Jersey will serve as LITs for this project, with Trustee Council oversight.

Restoration Objectives

The objective is to implement habitat restoration projects (Mad Horse Creek wet meadows and saltmarsh, DE goose pasture, Oyster reef) to restore an equivalent number of adult and juvenile birds lost due to the spill (Table 1) through the enhancement of degraded wetland, wet meadow, grassland, and oyster reef habitat. The resulting increase in invertebrate and fish biomass (wetland habitat, oyster reef) and upland vegetation (wet meadow, pasture, and grassland habitat) will serve as food sources that, once adjusted to account for trophic levels and ecological transfer efficiencies, can reasonably be expected to enhance bird biomass by an amount sufficient to offset documented bird losses.

Scaling Calculations – General

Scaling calculations include both direct and indirect injuries (i.e., direct mortality from the spill as well as indirect mortality due to lost productivity). Injuries are scaled by guild based on approximate weight and diet of the birds (Table 2).

To estimate the amount of restored habitat required to offset documented injuries, using the approach in French McCay and Rowe (2003), bird loss must first be converted from an "individuals lost" metric to a biomass basis (i.e., kilograms of bird biomass lost). This conversion is made by multiplying the numbers of birds lost by the estimated weight per bird. For direct injury, the adult weight is used. For indirect injuries (lost fledgling production), the juvenile weight is used[3]. Bird biomass lost is then “transferred” into an equivalent amount of estuarine wetland secondary productivity (for dabbling ducks and shorebirds), oyster reef secondary productivity (for piscivorous/omnivorous birds), or wet meadow and grassland primary productivity (for geese and swans) based on energy transfer efficiencies between trophic levels (i.e., between productivity generated by the restored marsh or oyster reef and the potential contribution of this productivity to bird biomass, taking intervening consumers into account). Transfer ratios were obtained from French McCay and Rowe’s (2003) review of relevant ecological efficiency literature. Transfer ratios used for *Athos* scaling calculations also are consistent with ratios used in the Final Restoration Plan and Environmental Assessment developed for the 7 April 2000 oil spill at Chalk Point on the Patuxent River, Maryland (NOAA et al. 2002). In the final step of the scaling analysis, the area of enhanced oyster reef, restored wetland, wet meadow, or grassland habitat required to offset specified injuries is calculated based on productivity information per unit area for these habitats obtained from relevant scientific literature. Species-specific scaling calculations are described in more detail below.

[3] For several of the smaller guilds, representative juvenile weights were not readily available; however, these species represent a very small fraction of the overall biomass.

Table 2. Overview of restoration scaling for bird losses.							
Guilds	**Direct Injury**	**Indirect Injury**	**Selected Species[1]**	**Weight[2] (kg) [Adult/ Juvenile]**	**Total Biomass[3] (kg) [Adult/ Juvenile]**	**Primary Diet**	**Restoration Project**
Dabbling ducks	605	1,764	Mallard	1.21/1.09	732/1,923	Invertebrates	Marsh
Diving ducks	82	187	Bufflehead	0.37	100	Fish	Oyster Reef
Diving birds	64	94	Double-crested cormorant	2.3	363	Fish	Oyster Reef
Gulls	1,072	1,874	Ring-billed gull	0.53/0.36	568/675	Fish/ Omnivorous	Oyster Reef
Shorebirds	55	79	Sanderling	0.06	8.0	Invertebrates	Marsh
Wading birds	10	17	Great blue heron	2.3	62	Fish	Oyster Reef
Swans and geese	1416	4540	Canada goose	3.96/2.20	5,607/9,988	Plants	Wet Meadow/ Grassland
Kingfishers	4	6	Belted kingfisher	0.15	1.5	Fish	Oyster Reef

1. The representative species is selected based on the most prevalent species for each guild represented in the recovered oiled birds following the spill, as reported in the Preassessment Data Report (NOAA 2006). For shorebirds, for which no oiled birds were recovered, the sanderling is chosen as a mid-weight bird spotted during bird observations.
2. Weights are based on data from the British Trust for Ornithology (BTO), with the exception of great blue herons, which are based on data from the Cornell Lab of Ornithology. When both male and female weights are available, an average is used. For mallards, gulls, and Canada geese, juvenile weights are available and included in indirect injury biomass calculations. Ring-billed juvenile weight is assumed equal to BTO juvenile weight estimates for common gulls (adult common gulls average 0.41 kg, slightly smaller than ring-billed gulls). Juvenile (fledgling) weight for Canada geese is the average reported in LeBlanc (1987) for Moffit's Canada Goose (*B. c. moffitti*), a subspecies similar in size to the Atlantic Canada Goose (*B. c. canadensis*)
3. Total Biomass is calculated as the sum of direct injury multiplied by adult weight and indirect injury multiplied by juvenile weight (if available). If juvenile weight is not available, total biomass is weight per bird multiplied by the sum of direct and indirect injury.

Scaling Calculations - Invertebrate Consumers

Scaling calculations for dabbling ducks and shorebirds are summarized in Table 3. Estimates of average adult and juvenile bird weights are based on data available from the British Trust for Ornithology[4]. For these guilds, the Trustees use secondary production as the "base" measure of productivity, from which adjustments for trophic transfer efficiencies are made. From a trophic level perspective, secondary production is "closer" to invertebrate consumers and so is an appropriate starting point for the scaling analysis. For these guilds, use of primary production as

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[4] For more information on the British Trust for Ornithology, see Robinson (2005). Data for the great blue heron are from the Cornell Lab of Ornithology (http://www.birds.cornell.edu/AllAboutBirds/BirdGuide/).

the "base" measure of productivity would require an additional set of assumptions regarding transfer efficiencies from primary to secondary production, and so is less preferable. The invertebrate production of an improved Mad Horse Creek marsh is also a reasonable approximation of the prey that these species consume.

As indicated in Table 3, the Trustees assume an ecological efficiency "transfer ratio" of 2 percent for birds feeding on invertebrate prey (i.e., 50 kg of invertebrate prey biomass is needed to generate 1 kg of bird biomass). As noted above, this assumption is consistent with estimates developed in French McCay and Rowe's (2003) review of relevant ecological efficiency literature and scaling calculations conducted in the Final Restoration Plan and Environmental Assessment developed for the 7 April 2000 oil spill at Chalk Point on the Patuxent River, Maryland.

Table 3. Scaling Calculations: Invertebrate Consumers.

Guild	**Selected Species**	**Biomass (kg) (Table 2)**	**Ecological Efficiency[1]**	**Compensatory Secondary Production Required[2] (kg dw)**	***Spartina* Marsh Secondary Productivity[3] (kg dw per acre)**	***Spartina* area required[4] (acres)**
Dabbling Ducks	Mallard (Adult/ Direct Injury)	732	2%	8,053	1,153	7.0
Dabbling Ducks	Mallard (Juvenile/ Indirect Injury)	1,923	2%	21,150	1,153	18.3
Shorebirds	Sanderling	8.0	2%	88	1,153	0.1
					Total	**25.4**

1. Ecological efficiencies are calculated relative to benthic infaunal detritivores and omnivores, as summarized in French McCay and Rowe (2003) and their review of relevant literature.
2. Compensatory Production Required (kg dw)= Weight of Birds Lost (kg ww)*0.22 (kg dw/kg ww) / Ecological Efficiency (%). Conversion from dry weight to wet weight assumes dry weight = 22% of wet weight (French McCay and Rowe 2003).
3. As estimated in French McCay and Rowe (2003), assuming a benthic faunal productivity of 20.8 (g DW/m^2-yr), 50 year functional life for the created marsh, restoration beginning 3 years after the spill, and 15 years for the created marsh to reach maximum functionality (following a logistic recovery path), discounted at 3% annually. Injury is discounted to 2006, with restoration planned to begin in 2009. The calculations are modified for a maximum service level of 85 percent based on monitoring requirements that at least 85 percent of the project area be successfully colonized with either targeted species or similar, native species consistently over a three year period (requirements attached). French McCay and Rowe (2003) is based on a broad review of *Spartina* marsh secondary productivity, primarily from southern New England. *Athos* scaling calculations assume negligible contributions to benthic productivity from the existing habitat targeted for restoration. Conversion from hectares based on 1 hectare = 2.47 acres.

Application of this two percent ecological efficiency transfer ratio to duck and shorebird injuries and conversion from wet weight to dry weight (assuming dry weight is 22 percent of wet weight as applied in French McCay and Rowe (2003)) results in a restoration requirement of 29,239 kg (dry weight) of compensatory benthic production needed to address duck and shorebird losses[5].

The Trustees assume that a restored *Spartina* marsh will produce approximately 1,153 kg (dry weight) of benthic productivity per acre, consistent with French McCay and Rowe (2003). This

[5] 29,239 kg dw secondary prod. = ((732 kg ww + 1,923 kg ww + 8.0 kg ww) / 0.02 transfer efficiency) * 0.22 kg dw/kg ww.

estimate assumes a 50-year functional life for the restored marsh, with restoration beginning in 2009 and maximum functionality achieved in 15 years (following a logistic recovery path prior to that point)[6]. French McCay and Rowe (2003) estimates are based on a broad review of *Spartina* marsh secondary productivity, primarily from marshes in southern New England. Trustee scaling calculations conservatively assume negligible contributions to benthic productivity from the existing degraded and filled habitat targeted for restoration.

As shown in Table 3, the calculated biomass requirement (29,239 kg dw) divided by the productivity per acre (1,153 kg dw/acre) results in a restoration requirement of 25.4 acres to offset dabbling duck and shorebird guild losses.

Scaling Calculations – Piscivorous/Omnivorous Species

Piscivorous and omnivorous species are scaled based on trophic transfer of the invertebrate productivity of an oyster reef. French McCay and Rowe (2003) provide a basis for scaling piscivorous and omnivorous species to invertebrate productivity, with an ecological efficiency of 0.4 percent.[7] To estimate the amount of additional benthic macroinvertebrates made available to predators such as fish by creation of an oyster reef, the Trustees rely on the productivity model created for an oyster reef restoration project in the Patuxent River (French McCay et al. 2002), augmented by site-specific data from the NJ/DE oyster restoration program.[8] Scaling calculations for piscivorous and omnivorous species are summarized in Table 4. The total biomass requirement of 77,851 kg afdw is split to provide relative acreages of 2:1 between the Middle Seed bed and Over the Bar enhancement projects. Given the relative productivities of the two sites (1,248 and 740 kg afdw/acre, respectively, for a weighted average of 1,079 kg afdw/acre), a final reef size of 72 acres is required, split as 48 acres at the Middle Seed bed and 24 at the Over the Bar bed.

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[6] The French McCay and Rowe (2003) productivity estimate assumes restoration begins three years after the spill. For the Athos spill, all injuries and restoration projects are discounted to 2006. Restoration is assumed to begin in 2009, as in the calculations in French McCay and Rowe (2003).

[7] The ecological efficiency represents a two-step trophic transfer. Birds consuming fish have an ecological efficiency of 2 percent; fish consuming invertebrates have an ecological efficiency of 20 percent (French McCay et al. 2002). The product of the efficiencies (0.4 percent) represents birds scaled to invertebrate production.

[8] For more detailed calculations on oyster reef productivity, please see the scaling paper for subtidal injuries.

Table 4. Scaling Calculations: Piscivorous/Omnivorous Consumers.				
Guild	**Selected Species**	**Biomass (kg) (Table 2)**	**Ecological Efficiency[1]**	**Compensatory Secondary Production Required[2] (kg afdw)**
Gulls	Ring-billed gull (Adult/ direct injury)	568	0.4%	24,999
Gulls	Ring-billed gull (Juvenile/ indirect injury)	675	0.4%	29,684
Diving Ducks	Bufflehead	100	0.4%	4,379
Diving Birds	Double-crested cormorant	363	0.4%	15,990
Wading Birds	Great blue heron	62	0.4%	2,732
Kingfishers	Belted kingfisher	1.5	0.4%	66
Total Compensatory Biomass				**77,851[3]**
Average discounted cumulative productivity (kg afdw/acre) [based on 2:1 split between Middle Seed bed and Over the Bar bed]				1,079
Acres of Oyster Reef				**72**
Acres at Middle Seed bed /Over the Bar bed				**48/24**

1. Ecological efficiencies are calculated relative to benthic infaunal detritivores and omnivores, as summarized in French McCay and Rowe (2003) and their review of relevant literature. Birds consuming fish have an ecological efficiency of 2 percent; fish consuming invertebrates have an ecological efficiency of 20 percent. The product of the efficiencies (0.4 percent) represents piscivorous birds scaled to invertebrate production.
2. Compensatory Production Required (kg afdw)= Weight of Birds Lost (kg ww)*0.22 (kg dw/kg ww)*0.8 (kg afdw/kg dw) / Ecological Efficiency (%). Conversion from dry weight to wet weight assumes dry weight = 22 percent of wet weight (French McCay and Rowe 2003). Conversion from dry weight to ash free dry weight (afdw) assumes afdw = 80 percent of dry weight (Bahr and Lanier 1981).
3. Values do not exactly sum to total due to rounding.

Scaling Calculations – Herbivorous Species

The Trustees modified the scaling approach used for other guilds to estimate compensation required to offset geese losses. Estimates of average adult Canada geese weights were obtained from information provided by the British Trust for Ornithology (Robinson 2005). Average juvenile weights were obtained from Leblanc (1987).[9] Geese are herbivores, and therefore consume plant biomass directly. While wetland restoration is an appropriate and effective approach for generating secondary (benthic) productivity utilized by coastal bird communities, there are more cost-effective approaches for generating the primary production (i.e., vegetation) likely to be consumed by geese, particularly since they frequently feed in more upland areas. In

[9] Juvenile (fledgling) weight is the average reported in LeBlanc (1987) for Moffit's Canada Goose (*B. c. moffitti*), a subspecies similar in size to the Atlantic Canada Goose (*B. c. canadensis*).

light of these considerations, the Trustees scaled geese losses to restoration of wet meadow, pond, and pasture/grassland habitat.

For these reasons the Trustees use primary production as the "base" measure of productivity, from which adjustments for trophic transfer efficiencies are made. As indicated in Table 5, the Trustees assume an ecological efficiency "transfer ratio" of 0.03 percent for birds feeding on a mixture of *Spartina* and microalgae typical of northeast salt marshes (French McCay *et al.* 2002), i.e., approximately 3,333 kg of plant biomass is needed to generate one kg of bird biomass. This assumption is consistent with a review of relevant ecological efficiency literature conducted in the Final Restoration Plan and Environmental Assessment developed for the 7 April 2000 oil spill at Chalk Point on the Patuxent River, Maryland. Application of this 0.03 percent ecological efficiency transfer ratio to geese injuries and conversion from wet weight to dry weight (assuming dry weight is 22 percent of wet weight as applied in French McCay and Rowe (2003)) results in a restoration requirement of approximately 4.1 million kg and 7.3 million kg (dry weight) of compensatory primary production needed to address direct and indirect injuries, respectively, to geese and swans.

Because of the magnitude of geese injuries and size limitations inherent to specific projects, compensation for injuries to geese is spread over several suitable projects. The first is a wet meadows project at Mad Horse Creek (30 acres); the second is a pond/pasture enhancement project in New Castle County, DE (22.9 acres), and the third is a grasslands project at Mad Horse Creek (100 acres).

The Mad Horse Creek areas for wet meadows and grassland projects, as well as the proposed area at Blackbird Reserve, are currently in active agriculture. The baseline productivity – the productivity currently consumed by herbivorous birds – is assumed to be the agricultural waste following harvest. Several studies have investigated the availability of this material to birds, specifically migratory waterfowl and geese. Corn is chosen as the proxy species for agricultural areas, given its prevalence and readily available data. The average of three reported values of waste corn following standard harvest practices is 131 kg per acre (Baldassarre and Bolen, undated; Warner et al., 1989; Ringelman, 1988). The discounted net productivity per acre is 3,170 kg per acre, for the fifty-year lifespan used for other herbivorous bird projects.

For the wet meadows project at Mad Horse Creek, the Trustees assume that restoration will begin in 2009, and that a restored wet meadow habitat will cumulatively produce approximately 133,517 kg (dry weight) of additional primary productivity per acre over the 50-year project duration assumed for scaling purposes. To develop this estimate, wet meadow annual primary productivity was calculated based on the average net annual productivity of several sedges and rushes in the United States (Mitsch and Gosselink, 1986). Four common species (*Carex atheroides, Larex lacustris, Juncus effusus,* and *Scirpus fluviatilis*) were included, for a net annual productivity of 7,155 kg per acre. Scaling calculations assume that a maximum vegetation productivity of 85% is reached in five years, based on NJDEP mitigation requirements that specify a target vegetation requirement of 85%, with less than 10% invasive plants, at the end of the five-year monitoring program.[10]

The proposed site of the pond and pasture project is the Blackbird Reserve and Wildlife Area in New Castle County. Restoration will begin in 2009 and is expected to produce an average of 100,909 kg (dry weight) per acre over the lifetime of the project, for all habitat types. The pasture section will be planted with white clover, creeping red fescue, and chewing fescue. For scaling purposes, the productivity of the pasture areas is assumed to be the average of the three species. According to published values, the productivity range for white clover is between 1,800 and 2,800 kg per acre (average 2,300), while creeping red fescue ranges from 6,110 to 6,920 kg per acre (average 6,440) and chewing fescue from 5,670 to 6,440 kg per acre (average 5,790).[11] The three species are averaged to provide a productivity of 4,860 kg per acre of pastureland. The net productivity over the project lifetime is calculated assuming a 50-year project lifespan, 50 percent productivity in the first year, and 100 percent in the following 49 years.

For the pond/wetland component, the Trustees average the estimated primary productivity of small ponds with wet meadows, to account for ecological benefit arising from phytoplankton, algae, and aquatic vegetation in the pond as well as vegetation on the shallow sloped banks, resulting in an additional lifetime productivity of 86,648 kg per acre. For wet meadows, the value derived above for Mad Horse Creek is applied. For ponds, a primary productivity of 1,805 kg per acre is used, which incorporates phytoplankton and submerged macrophytes (Russo, 1978). The net pond productivity over the project lifetime is calculated assuming a 50-year project lifespan, 50 percent productivity in the first year, and 100 percent in the following 49 years.

In the agricultural area, 23.6 acres of agricultural food plots will be planted. Of the acreage, 20 percent (4.7 acres) will be left unharvested. For the agricultural standing crop component, corn is chosen as a proxy crop. The 2003-2007 average yield for corn in New Castle County is 137.7 bushels per acre (USDA NASS, undated). Given a standardized weight of 56 pounds per bushel (7 CFR §810.404) and average moisture of 15.5%, the net annual productivity is 3,320 kg per acre. The additional productivity above baseline over the lifetime of the project is 68,508 kg per acre. The net productivity over the project lifetime is calculated assuming a 50-year project lifespan and 100 percent productivity beginning in the first year, since the land is currently in agricultural use.

For the grassland component of Mad Horse Creek, the lifetime productivity is estimated as 47,194 kg per acre. The yearly productivity estimate of 2,120 kg per acre is based on annual aboveground net primary production from a grassland site in Osage, Kansas most similar in rainfall and average temperature to southern New Jersey during a multi-year study (Sims and Singh 1978). Grassland scaling calculations assume 50% of "full" productivity in the first year followed by full productivity for the ensuing 49 years.

[10] Because this restoration project is focused solely on producing herbaceous vegetation suitable for geese and swans, not complete marsh structure or benthic invertebrate communities, the scaling calculations assume maximum productivity by the end of the five-year monitoring program.
[11] White clover: Duke, 1983 and UCSAREP, undated; Red chewing fescue and creeping fescue: Chastain et al. 2002.

Table 5. Scaling Calculations: Herbivorous Consumers.

Guild	Selected Species	Biomass (kg) (Table 2)	Ecological Efficiency[1]	Compensatory Primary Production Required[2] (kg dw)
Swans and geese	Canada geese (Adult/Direct Injury)	5,607	0.03%	4,112,064
Swans and geese	Canada geese (Juvenile/Indirect Injury)	9,988	0.03%	7,324,533
			Total	**11,436,597**

1. Ecological efficiencies are calculated relative to benthic infaunal detritivores and omnivores, as summarized in French McCay *et al*. (2002).

2. Compensatory Production Required (kg dw)= Weight of Birds Lost (kg ww)*0.22 (kg dw/kg ww) / Ecological Efficiency (%). Conversion from dry weight to wet weight assumes dry weight = 22% of wet weight (French McCay and Rowe 2003).

Project	Net Productivity (kg dw/acre)[3]	Available Acreage (acres)	Available Primary Production (kg dw)
Wet Meadow (Mad Horse Creek)[4]	133,517	30	4,005,516
Managed Pasture (Blackbird Reserve)[5]	112,387	16	1,798,195
Pond (Blackbird Reserve)[6]	86,648	2.2	190,625
Agricultural Crops (Blackbird Reserve)[7]	68,508	4.7	321,990
Grasslands (Mad Horse Creek)[8]	47,194	100	4,719,354
	Total Primary Productivity		11,035,681

3. All calculations assume 50 years of productivity, a baseline productivity equal to waste corn (due to current agricultural use), and that projects will begin in 2009 and be discounted at 3% annually.
4. Wet meadow annual primary productivity is based on representative sedges and rushes (Mitsch and Gosselink, 1986). Scaling calculations assume that a maximum vegetation productivity of 85% is reached in five years, based on NJDEP mitigation requirements.
5. Managed pasture is calculated as the average annual productivity of the three species planted in the area (white clover, creeping red fescue, and chewing fescue). Pasture scaling calculations assume 50% of "full" productivity in the first year followed by full productivity for the ensuing 49 years.
6. Pond productivity is calculated as the average of pond productivity (phytoplankton and aquatic vegetation) and wet meadow productivity, due to the combination of pond and vegetated banks. For the pond productivity, the first year is calculated at 50% of full productivity, followed by full productivity for the ensuing 49 years.
7. Agricultural productivity is based on corn as a proxy, given that it is a likely crop in the area. Annual productivity of corn per acre for Delaware agricultural lands is used, along with standardized assumptions regarding the weight of corn per bushel and the moisture content. For the agricultural productivity, full productivity is assumed for the entire 50 years, given the current use as agricultural lands.
8. Grassland primary productivity is conservatively assumed equal to the highest annual productivity observed at a grassland site (Osage, Kansas) most similar in rainfall and average temperature to southern New Jersey during a multi-year study (Sims and Singh 1978). Grassland scaling calculations assume 50% of "full" productivity in the first year followed by full productivity for the ensuing 49 years.

The Mad Horse Creek and Blackbird Reserve projects provide 3.5 percent less than the 11,436,597 total discounted plant biomass calculated for restoration purposes. However, given uncertainties inherent in injury and restoration scaling calculations, in the Trustees' judgment, the proposed restoration projects are appropriately sized to offset *Athos*-related injuries to herbivorous birds.

Probability of Success

Restoration of wetlands, meadows, and grasslands is feasible, with proven techniques, established methodologies, and documented results. Local, state, and federal agencies have successfully implemented similar projects in this region. The Mad Horse Creek and Blackbird projects are located on land already owned by the government. For these reasons, the Trustees believe that this project has a high likelihood of success.

While final details of the marsh restoration projects remain to be fully developed, the Trustees will carefully monitor plant handling and installation to ensure that appropriate guidelines are being followed. With respect to revegetation efforts, all plant material will be inspected to ensure that it is healthy and vigorous, and will be protected during mobilization from drying and physical damage. Container grown plants will be treated with a slow-release fertilizer at the time of planting. Replanting will occur if a significant number of plants die.

Oyster bed enhancement is generally considered to be the most effective method for supplementing oyster populations. The on-going program in the Delaware River has resulted in large increases in oyster numbers, particularly based on the size of the projects relative to the overall area of nursery beds. The probability of success for this project (i.e., the likelihood of successfully producing a functioning oyster reef) is high.

Performance Measures and Monitoring

Mad Horse Creek

Project performance at Mad Horse Creek will be assessed by comparing quantitative monitoring results to predetermined performance standards. These standards will be based on guidelines established by the New Jersey DEP for assessing wetland mitigation projects (attached). Restored habitats will be monitored twice a year, in early spring and fall, for five full growing seasons. Monitoring assessments will include documentation of hydrologic regime, soil characteristics, plant species present and confirmation of planned site grading and elevation. At the end of the five-year monitoring period, a survival rate of 85 percent of planted vegetation (and/or similar native vegetation) should be documented; less than 10 percent of plant species should be characterized as non-native, invasive, or noxious. At the conclusion of monitoring, the created wetland areas should be delineated using federal standards and the final acreage corroborated with compensatory requirements.[12]

The monitoring program for this project will use these standards to determine whether the project goals and objectives have been achieved, and whether corrective actions are required to meet the goals and objectives. In the event that performance standards are not achieved or monitoring suggests unsatisfactory progress toward meeting established performance standards, corrective actions will be implemented. Possible corrective actions include regrading the area to proper elevations and replanting appropriate vegetation. Any necessary corrective actions would be funded by the contingency component of the project costs (Table 6).

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[12] Specifically, wetlands will be delineated using the Federal Manual for Identifying and Delineating Jurisdictional Wetlands (Federal Interagency Committee for Wetland Delineaton 1989).

Blackbird Reserve Wildlife Area

Project performance at Blackbird Reserve will be assessed by evaluation of the acreage allocated to each use (pasture, agricultural, pond). For the pasture plantings, monitoring will include documentation of the acreage and evaluation of the species. A survival rate of 85 percent of planted vegetation (and/or similar native vegetation) should be documented; less than 10 percent of plant species should be characterized as non-native, invasive, or noxious; and the entire area should be vegetated. For the agricultural area, monitoring will include documentation of the acreage left unharvested for wildlife use at the end of the season. In the pond area, monitoring will entail documentation of the overall acreage and evaluation of the bank vegetation. An assessment will be made to determine whether sufficient vegetation is present to stabilize the banks. If the acreages are less than specified in the plan, modifications will be made to planting and to the agreement with the farmer for the agricultural lands, as necessary. Any necessary corrective actions would be funded by the contingency component of the project costs.

Oyster Reef Sanctuary

Performance measures and monitoring for the oyster reef sanctuary will focus on two key parameters that will function as a trigger for use of contingency funds (if necessary). First, the Trustees will confirm that the intended acreage of oyster reef is successfully created. As noted previously, scaling calculations suggest that approximately 72 acres of created oyster reef (approximately 48 acres in the Middle Seed beds and 24 acres in the Over the Bar beds) are needed to offset *Athos*-related injuries to benthic biota. Second, the Trustees will measure spat/oyster densities on created oyster reefs. This parameter also is a key driver of scaling results.

Confirmation of the size of the created oyster reefs will be a "one-time" monitoring event, occurring as soon as practicable after project implementation. Monitoring of spat/oyster densities will occur annually, beginning immediately following placement of transplanted, seeded cultch (Middle Seed beds) and the expected peak of natural setting on cultch placed by the Trustees (Over the Bar beds). Monitoring of spat/oyster densities will continue for a total of six years, corresponding to the 6 year project life assumed in scaling calculations.

Annual monitoring will be performed by Dr. Powell and colleagues at Haskins Laboratory of Rutgers University. The *Athos* sites will be integrated into regular monitoring conducted by the laboratory, affording cost efficiencies while securing the professional expertise of Dr. Powell and his staff. The number of spat or oysters will be determined using divers over a three day period each year. For every 25 acres of created reef, 3 transects will be established, with 12 quarter-meter quadrat collection sites per transect. Divers will collect shell and established biota within each of these quadrats and place them in bags. The specimens will then be transported on-shore where they will be counted and identified in the laboratory. The total cost of spat/oyster monitoring is estimated at $760 per acre and includes diver time, boat operations, and staffing for the laboratory identification component (Table 8).

If measured spat/oyster densities do not meet the levels assumed in scaling calculations as described under scaling for subtidal injuries, the Trustees will utilize contingency funds to create additional reef areas and/or relocate the existing reefs to offset the observed shortfall (or to make up for as much shortfall as possible if contingency funds are insufficient to offset it entirely). Although scaling calculations also include the productivity of other benthic biota expected to be enhanced by oyster reef creation (e.g., mud crabs, grass shrimp, and small crustaceans), the Trustees make the simplifying assumption that the density of these biota will track the acreage of the reef site. Thus, confirmation of the area of created oyster reef and oyster densities (and corresponding corrective action, if necessary) will provide sufficient measures of project success, reasonably balancing the need for monitoring with the costs of such efforts.

Approximate Project Costs

Table 6 provides a summary of expected costs for restoring 25.4 acres of wetland habitat, 30 acres of wet meadow habitat, and 100 acres of grassland habitat at Mad Horse Creek to compensate for injuries to invertebrate-consuming and herbivorous birds. Tables 8 and 9 provide a summary of expected costs for creation of 69.9 acres of oyster reef in the Delaware River. The location and disposition of Mad Horse Creek will make the construction costs low relative to most other potential restoration sites. Relatively low project costs result from the fact that both properties are government-owned (thus no need to purchase property or easements) and the expectation, based on available information, that sediment contamination levels are low enough to allow placement of excavated sediment on-site (and used for grassland habitat restoration).

Detailed design and planning efforts are currently underway, and may result in modifications to information presented above. The NJDEP has already spent $9,052 for aerial photos and survey work in GIS format and is in the process of contracting for complete design work at a cost of $181,696.20, resulting in a total design/planning cost estimate of approximately $190,000, split between Table 6 below and costs described in the Shoreline scaling paper. Based on experience with similar projects in the region, the Trustees expect the 25.4 acre tidal portion of the project and 30 acre wet meadow portion to cost $9,473,052 in total.

Grassland restoration costs are included in the unit costs for wetland and wet meadows restoration. As noted previously, grassland restoration is an essential project component and would take place even in the absence of injuries that can be scaled to it, as it serves as a means for on-site, upland disposal of excavated sediments. Contouring and revegetation of such excavated sediments is standard practice. For these reasons, there is no additional cost associated with the grassland restoration project component.

Table 7 provides a summary of project costs for the pond and pasture project in New Castle County, DE. The costs include excavation of a 2.2 acre pond, planting and maintenance for 16 acres of pasture, and oversight of the agricultural lands. Maintenance costs reflect semi-annual mowing of the pasture areas throughout the lifespan of the project, to ensure suitability to geese.

Table 6. Summary of Project Costs: Mad Horse Creek Restoration. ***COSTS ARE NOT FINAL***

Cost Element	Per Acre	Available Acres	Total
Project implementation			
Detailed Design/Planning			$114,810
Estimated Wetland Restoration Costs	$150,000	25.4	$3,810,000
Estimated Wet Meadows Restoration Costs	$150,000	30	$4,500,000
Estimated Grassland Restoration Costs	$0	100	$0
Sub-total		155.4	$8,424,810
Monitoring			$295,085
Technical Oversight			$753,157
Total			$9,473,052

Notes:

(a) Grassland restoration costs are included in the unit costs for wetland and wet meadows restoration. Grassland restoration is an essential project component and would take place even in the absence of injuries that can be scaled to it, as it serves as a means for on-site, upland disposal of excavated sediments. Contouring and revegetation of such excavated sediments is standard practice. For these reasons, there is no additional cost associated with the grassland restoration project component.

Table 7. Summary Of Project Costs: Blackbird Reserve Wildlife Area Pond And Pasture Restoration ***COSTS ARE NOT FINAL***

Excavation	$7,260
Pasture Creation	$5,280
Wetland Planting	$3,000
Project Administration	$2,710
Maintenance	$50,000
Construction Sub-total	$68,250
Monitoring	$4,400
Technical Oversight	$6,464
Trustee Oversight	$11,794
Total	$90,908

Tables 8 and 9 provide a summary of the costs for enhancing 72 acres of oyster reef.[13] For the Middle Seed bed project, two barge plantings of shell, initially in the seed beds and then transferred to the nursery beds, are included, with a total bed size of 48 acres. For the Over the Bar bed, one barge planting of shell is included, with a total bed size of 24 acres.

[13] Written communication from Russell M. Babb, Jr., Principal Fisheries Biologist, New Jersey Division of Fish and Wildlife. July 21, 2006; Personal communication, Richard Cole, Delaware Department of Natural Resources and Environmental Control, Division of Fish and Wildlife.

Table 8. Summary of Project Costs: Creating a 48 acre oyster reef in "Middle Seed" bed area (NJ). ***COSTS ARE NOT FINAL***

Cost Element	**Per Bushel**	**Per acre**	**Project**
Project Implementation			
Spat planting at seed beds (1,500 bushels per final acre)			
Clam Shell	$0.85	$1,275	$61,200
Loading Fee	$0.10	$150	$7,200
Planting (Tug + Barge)	$1.00	$1,500	$72,000
Spat transplant (1,000 bushels recovered per 1,500 planted; planted at 1,000 bushels per acre)			
Re-harvest/Transplant	$1.50	$1,500	$72,000
Subtotal		$4,425	$212,400
Monitoring		$760	$36,480
Technical Oversight			$71,340
Total			$320,220

Table 9. Summary of Project Costs: Creating a 24 acre oyster reef in "Over the Bar" beds (DE). ***COSTS ARE NOT FINAL***

Cost Element	**Per Bushel**	**Per acre**	**Project**
Planting at Over the Bar Beds (2,000 bushels per acre)			
Project Implementation Total Shell + Planting Costs	$2.05	$4,100	$98,400
Monitoring		$760	$18,240
Technical Oversight			$35,670
Total			$152,310

Environmental and Socio-Economics Impacts

Wetlands are widely recognized as providing numerous ecological functions, including providing habitat for juvenile fish and shellfish, exporting detritus (energy source for the aquatic food web) into the estuary, and increasing water quality by filtering sediments and other pollutants from the water column. Wetlands also provide many additional benefits such as storm surge protection, habitat for birds and mammals, and enhanced recreational use of the area by increasing the numbers of aquatic species. Wet meadow and upland restoration will provide birds and terrestrial biota with a variety of dietary, sheltering, and nesting services.

Habitat restoration at Mad Horse is not expected to have any significant adverse environmental impacts. Any impacts to existing habitats from project construction are expected to be temporary. Because lands intended for restoration already are government-owned, the Trustees do not expect the project to have any significant adverse economic impacts.

In addition to enhancing benthic and fish biomass, the created oyster reef may improve water quality. Oysters are known to reduce suspended particulate matter and consume phytoplankton that contribute to anoxia in bottom waters, thereby improving water clarity and light penetration critical for aquatic life.

Oysters are a harvestable resource and economically important in the area. While oyster harvesting will not be allowed in the sanctuary, these areas could provide broodstock populations. There are numerous commercial and recreational fisheries and supporting industries that could benefit from such enhanced production of naturally produced oysters and the reef structure. Creating a new sanctuary will eliminate some of the currently available area for oyster harvesting. This decrease will be small, however, because the area withdrawn is small compared to the area remaining available, and commercial harvesting is minimal in the areas selected.

Evaluation

The identified projects are consistent with the Trustees' evaluation criteria, and result in restoration of the same or similar types of injury (i.e., bird biomass) in the same geographic area of the spill. The selected projects provide many of the same ecological services, are readily available, have a high likelihood of success, and can be scaled to quantified injuries.

The projects at Mad Horse Creek are a cost-effective method to address injuries to multiple guilds of birds along the Delaware River. The estimated cost per acre for marsh and wet meadows for Mad Horse Creek is $150,000, which is below per acre costs for nearby wetlands restoration projects (e.g. Woodbridge Creek). Additionally, these costs include the creation of an extensive area of grasslands, which also contributes to addressing the injury to herbivorous birds. Marsh restoration and enhancement is consistent with state, federal, and local restoration goals established for the Delaware River.

Goose habitat creation on Blackbird Reserve is a cost-effective means of compensating for this injury. This project adds forage and resting areas desirable to geese to an important corridor for migratory waterfowl. The project is on state-owned land and will require minimal restoration, resulting in a cost-effective approach to addressing a portion of the goose injury.

The selection of oyster reef enhancement to address a portion of the bird injury is consistent with the Trustees' evaluation criteria. It is cost-effective, reasonably compensates for omnivorous bird loss biomass attributable to the *Athos* spill through creation of additional benthic invertebrates, and will be implemented in the Delaware River in areas as close to spill-affected locations as conditions needed for oyster survival allow. Creating and enhancing oyster reefs is also a cost-effective, low risk restoration approach, and is consistent with existing federal, state, and local restoration goals for the Delaware River and Bay[14]. The likelihood of project success is high, as this effort will augment an existing, successful program for oyster reef creation.

The Trustees do not expect any adverse impacts. Other than risk to workers, there is no significant risk to human health and safety.

References

Bahr, L.N. and W.P. Lanier. 1981. The ecology of intertidal oyster reefs of the South Atlantic coast: a community profile. U.S. Fish and Wildlife Service, Office of Biological Services, Washington DC. FWS/OBS-81/15.

Baldassarre, G.A. and E.G. Bolen. Undated. Management of Waste Corn for Waterfowl Wintering on the Texas High Plains. Contribution No. T-9-504 of the College of Agricultural Sciences, Texas Tech University (Department of Range, Wildlife and Fisheries Management - Management Notes).

Chastain, T.G., W.C. Young, and G. Gingrich. 2002. Differential Response of Fine Fescue Cultivars to Nonthermal Residue Management. Progress Report for FY02; Grass Seed Cropping Systems for a Sustainable Agriculture; accessed online at http://gscssa.wsu.edu/progress/02/702.htm.

Duke, J.A. 1983. Handbook of Energy Crops [unpublished] Data for *Trifolium repens* presented in the Purdue University New Crop Resource Online Program; accessed online at http://www.hort.purdue.edu/newcrop/duke_energy/trifolium_pratense.html

French McCay, D., C. Peterson, M. Donlan. 2002. Restoration Scaling of Benthic, Aquatic, and Bird Injuries to Oyster Reef and Marsh Restoration Projects. April 16, 2002. Prepared for NOAA for the Chalk Point/Swanson Creek Oil Spill. (Included as Attachment A to the subtidal scaling paper.)

French McCay, D.P and J.J. Rowe. 2003. Habitat restoration as mitigation for lost production at multiple trophic levels. Mar. Ecol. Prog. Ser. 264 (2003) 235–249.

Leblanc, Y. 1987. Egg mass, position in the laying sequence, and brood size in relation to Canada goose reproductive success. Wilson Bulletin. Vol. 99, no. 4, pp. 663-672.

Mitsch, W.J. and Gosselink, J.G. 1986. Wetlands (1st ed.). Van Nostrand Reinhold Co., New York.

National Oceanic and Atmospheric Administration (NOAA), Maryland Department of Natural Resources, Maryland Department of the Environment, U.S. Fish and Wildlife Service. 2002. Final Restoration Plan and Environmental Assessment for the April 7, 2000 Oil

[14] In 2001, representatives of DE and NJ, including both state regulatory agencies (DNREC/NJDEP), the Delaware River and Basin Commission (DRBC), the Delaware Estuary Program, the Shellfish Councils for both states, USFWS, and interested citizens began developing a bi-state oyster revitalization initiative.

Spill at Chalk Point on the Patuxent River, Maryland. November 2002. Available: http://www.darrp.noaa.gov/northeast/chalk_point/admin.html. NOAA Damage Assessment, Remediation, and Restoration Program, Silver Spring, MD.

National Oceanic and Atmospheric Administration (NOAA). 2006. Final Preassessment Data Report M/T *ATHOS I* Oil Ppill, Delaware River. Available: http://www.darrp.noaa.gov/northeast/athos/pdf/PADR.june.pdf. June 2006. NOAA Damage Assessment, Remediation, and Restoration Program, Silver Spring, MD.

Ringelman, J.K. 1988. Managing Agricultural Foods for Waterfowl. Section 13.4.3 in: Cross, D., and P. Vohs, (eds.). 1988. *Waterfowl Management Handbook*. Fort Collins, CO: U.S. Fish and Wildlife Service.

Robinson, R.A. 2005. BirdFacts: profiles of birds occurring in Britain & Ireland (v1.1, Jan 2006). BTO Research Report 407, BTO, Thetford (http://www.bto.org/birdfacts).

Sims, P.L. and J. S. Singh. 1978. The Structure and Function of Ten Western North American Grasslands. III. Net Primary Production, Turnover and Efficiencies of Energy Capture and Water Use. Journal of Ecology. Vol. 66, pp. 573-597.

University of California Sustainable Agriculture Research & Education Program (UCSAREP). Undated. White Clover. Cover Crop Database; accessed online at http://www.sarep.ucdavis.edu/ccrop/

U.S. Department of Agriculture National Agricultural Statistics Service (USDA NASS). Undated. Statistics by State (New Castle County Delaware, Corn for Grain, 2003-2007). Accessed online at http://www.nass.usda.gov/.

Warner, R.E., S.P. Havera, L.M. David, and R.J. Siemens. 1989. Seasonal Abundance of Waste Corn and Soybeans in Illinois. *The Journal of Wildlife Management*, Vol. 53, No. 1 (Jan., 1989), pp. 142-148.